DEW Line Clean Up Project
Landfarm Summary Report

Prepared by

Environmental Sciences Group
Royal Military College
Kingston, Ontario

March 2012
RMC-CCE-ES-12-04

To:

Nahed Farah P. Eng. M. Sc. GSC.
Program Support Officer
Defence Construction Canada
DCC/DGME PMO
180 Kent Street, 15th floor, Ottawa ON K1P 0B6

Dear Nahed,

This report summarizes the present status of the landfarms associated with the DLCU Project and presents ESG's recommendations for assessing the suitability of remediated landfarm soils for use elsewhere on site.

It should be noted that this report is a summary of work completed by ESG at DLCU sites. Full and complete records of all site remediation activities are retained in the ESG archives, and are available to DND and/or DCC upon request. The information presented in this report is based upon work undertaken by trained technical staff in accordance with both the DLCU protocol and generally accepted scientific and engineering practices current at the time the work was performed. The conclusions presented represent the best technical judgment of ESG, based on the data collected. The work was performed in specific testing areas, according to a specific cleanup design, and therefore the data collected can only be extrapolated within the context of the project scope. Any use made of this letter by a third party, or any decisions made based on it, are the responsibility of the third party.

Should you have any questions, please do not hesitate to contact me.

Regards,

Daniela Loock, Ph.D.
ESG DLCU Project Manager
Environmental Sciences Group
Royal Military College of Canada
PO Box 17000 Stn. Forces
Kingston, ON K7K 7B4

TABLE OF CONTENTS

1 Introduction

The Environmental Sciences Group (ESG) is participating in the environmental remediation of former Distant Early Warning (DEW) Line sites. The DEW Line Clean Up (DLCU) Project is supported by Defence Construction Canada (DCC), AECOM (formerly UMA Engineering Ltd.), and ESG. ESG's role during this multi-year project is to provide scientific advice and quality assurance services on behalf of the DLCU Project Management Office (PMO). The remediation is being undertaken in accordance with the DEW Line Cleanup Protocol (ESG 1992); the cooperation agreement between the Department of National Defence (DND) and the Inuvialuit Regional Corporation (IRC) (DGE 1996) for sites located within the Inuvialuit Settlement Region (ISR); and the cooperation agreement between DND and Nunavut Tunngavik Incorporated (NTI) (DGE 1998) for sites located within the Nunavut Settlement Area (NSA).

The goal of the DLCU Project is to remediate 21 DEW Line sites to an environmentally safe state and to prevent migration of contaminants into the food chain. The 21 sites, which are the responsibility of DND contain facilities that have been declared surplus to the requirements of the North Warning System (NWS). The project includes decommissioning of surplus structures, excavation of contaminated soils, remediation of landfills, and cleanup of surface debris.

The DLCU Project defines two classes of petroleum hydrocarbon contamination: Type A and Type B. Type A hydrocarbon-contaminated soil is comprised of the less mobile hydrocarbon fractions, including lubricating oils. Type B hydrocarbon-contaminated soil is composed of the more mobile, shorter chain and more volatile hydrocarbons, such as MoGas, jet fuel and diesel. In cases where soil has both hydrocarbon types present, its dominant hydrocarbon type classification is defined by the relative percentage of the two types. Soils with greater than 30% Type B of the total hydrocarbon content are considered Type B and may be treated in a landfarm.Type A hydrocarbon-contaminated soils are typically excavated and placed in the on-site non-hazardous landfill or are scarified. A screening level of 2,500 ppm total petroleum hydrocarbon (TPH) is used to assess whether soils are contaminated (EWG 2003).

This report summarizes the present status of the landfarms associated with the DLCU Project and presents ESG's recommendations for assessing the suitability of remediated landfarm soils for use elsewhere on the site.

2 Landfarms

A landfarm is a level area, defined by berms in which a large volume of Type-B hydrocarbon-contaminated soil is spread in a thin layer of 0.3 – 0.4 m thickness and treated to facilitate a reduction in hydrocarbon concentrations through biodegradation and volatilization. Remediation of contaminated soil by landfarming typically involves the addition of nutrients and water to the soil, followed by tilling to aerate the soil and stimulate microbial activity. Protocols for the construction and operation of landfarm facilities during the remediation of DEW Line sites may be found in the site-specific specifications.

The selection of location for and the design of a landfarm takes into account several factors, including topography, drainage and geology; the footprint of area required; the distance from ecologically sensitive areas, including marine and freshwater systems; the distance from water supplies; contaminated soil areas; and the accessibility of the landfarm location during the remediation work. The life cycle of the landfarm involves preparation of the ground; construction of roadways for access; construction of the landfarm facility; placement of Type B hydrocarbon-contaminated soils; nutrient application, moisture conditioning and tilling as required during treatment; installation of monitoring equipment around the perimeter of the landfarm; and closure of the facility including decommissioning of the monitoring equipment on completion of treatment of the contaminated soils.

3 Landfarms and the DEW Line Clean Up Project

3.1 The Use of Landfarms at DEW Line Sites

The remediation of the six DEW Line sites located within the ISR (BAR-1, BAR-2, BAR-3, BAR-4, PIN-M and PIN-1) has been completed. During the remediation activities, landfarming was used to treat Type B hydrocarbon-contaminated soil at two of the six sites (BAR-4 and PIN-1).

Fifteen of the DEW Line sites are located within Nunavut. The remediation of fourteen of these sites (PIN-2, PIN-3, PIN-4, CAM-M, CAM-1, CAM-2, CAM-3, CAM-4, CAM-5, FOX-M, FOX-2, FOX-3, FOX-4, and FOX-5) has been completed, while remediation activities continue at DYE-M. Landfarms were used in the remediation of Type B hydrocarbon-contaminated soil at the following 11 sites: PIN-3, PIN-4, CAM-2, CAM-3, CAM-4, CAM-5, FOX-M, FOX-2, FOX-3, FOX-5, and DYE-M. The landfarm at DYE-M is still in operation.

The operation and closure of landfarms constructed as part of the DEW Line Cleanup Project is guided by procedures outlined in the DLCU Landfarm Evaluation Protocol described below.

3.2 The DLCU Landfarm Evaluation Protocol

The DLCU Landfarm Evaluation Protocol was developed in 1999 by ESG as a process to determine that the hydrocarbon content of soil has been remediated to below 2,500 ppm (an example of the protocol can be found in ESG 2003). Until 2005, the Protocol used an approach in which the landfarm was divided into 12 m x 12 m grid cells and one composite sample comprised of five discrete locations collected at 0.3 m depth from within each cell was analyzed for TPH in the field laboratory. Driven by a need to manage the total volume of sampling and analysis required to close large landfarms, the Protocol was updated between 2004 and 2005. The current approach for landfarms that are larger than one hectare is to collect one discrete sample from each 10 m x 10 m grid cell in pre-determined semi-randomly scattered locations at 0.4 m depth, to analyze the samples for TPH in an accredited laboratory and to evaluate the results statistically. Individual one hectare sections of the landfarm may be closed when the results of the sampling indicate that the 95% upper confidence limit (UCL) for a particular section is less than 2,500 ppm TPH and that the TPH concentrations of all samples from this section are below 5,000 ppm. All sections of the landfarm must meet these criteria before the entire landfarm may be closed.

The 1999 (ESG 2003) and 2005 (ESG 2005) versions of the Landfarm Evaluation Protocol present equally valid methods of assessing whether soil within a landfarm has been remediated to below 2,500 ppm. In general, the 2005 Protocol is most appropriate for large landfarms or for situations in which robust data is required. The 1999 Protocol is suited to small landfarms (or sections of landfarms) and to situations in which a quick turnaround time is needed.

Once a landfarm has been determined to meet the closing criteria, the berms are graded to promote surface water runoff. If there was a geomembrane liner, it must be removed to a minimum depth of 0.3 m below the finished surface. Any cells of the landfarm containing soil that is co-contaminated with Tier I PCBs or lead must be capped in place under 30 cm of clean fill. A summary of information relating to all landfarms operated as part of the DEW Line Cleanup Project is provided in Table 1.

DEW Line Cleanup Landfarm Summary

Site Name	Land Claims Region	DLCU Site Status	Landfarm Sub-Sections	Landfarm Status	Closure	Cover Material Volume (m^3)	Tier I/ Type B Cell	TPH Concentration (95% UCL Mean)[1] [ppm]	TPH Concentration (Maximum) [ppm]	UTM Coordinates Corner Southeast Corner Northing	UTM Coordinates Corner Southeast Corner Easting	Volume (m^3)	Area (m^2)	Depth (m)	Landfarm Closure Reference(s)
BAR-1 (Komakuk Beach, YT)	Inuvialuit Settlement Region (ISR)	Remediation complete.	n/a	No landfarm constructed.	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
BAR-2 (Shingle Point, YT)	Inuvialuit Settlement	Remediation complete.	n/a	No landfarm constructed.	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
BAR-3 (Tuktoyaktuk,	Inuvialuit Settlement	Remediation complete.	n/a	No landfarm constructed.	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
BAR-4 (Nicholson Peninsula, NWT)	Inuvialuit Settlement Region (ISR)	Remediation complete.	n/a	Landfarm closed in 2000.	Berms flattened, and area reshaped.	n/a	Yes	Not calculated	2,000	7760630	502835	4,800 (Assuming 0.4 m depth.)	12,000	Not recorded. (Assumed to be 0.40 m.)	Environmental Sciences Group, 2000. Monitoring of Hydrocarbon Remediation Landfarm at BAR-4 (Nicholson Peninsula, NWT).
PIN-M (Cape Parry, NWT)	Inuvialuit Settlement	Remediation complete.	n/a	No landfarm constructed.	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
PIN-1 (Clinton Point, NWT)	Inuvialuit Settlement Region (ISR)	Remediation complete.	n/a	Landfarm closed in 2003.	Landfarm dewatered. Because of high moisture content, berms were not flattened, and area was not reshaped.	n/a	No	Not calculated	1,500	7720778	585891	2,970	5,940	0.5	Environmental Sciences Group, 2004. PIN-1 Site Remediation: Confirmatory Sampling 2003.
PIN-2 (Cape Young, NU)	Nunavut Settlement	Remediation complete.	n/a	No landfarm constructed.	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
PIN-3 (Lady Franklin Point, NU)	Nunavut Settlement Area (NSA)	Remediation complete.	n/a	Landfarm closed in 2005.	Berms flattened, and landfarm covered with 0.3 m of granular fill.	8,757	No	Not calculated	2,500	7597940	408440	11,680	29,190	0.4	Environmental Sciences Group, 2005. PIN-3 Site Remediation: Confirmatory Sampling 2004. (Memo: PIN-3-05-001) Environmental Sciences Group, 2010. CAM-2 (Gladman Point, Nunavut) Site Remediation: Confirmatory Sampling 2005. (Memo: ESG-CAM-2-092)

DEW Line Cleanup Landfarm Summary, cont'd

Site Name	Land Claims Region	DLCU Site Status	Landfarm Sub-Sections	Landfarm Status	Closure	Cover Material Volume (m^3)	Tier I/ Type B Cell	TPH Concentration (95% UCL Mean)[1] [ppm]	TPH Concentration (Maximum) [ppm]	UTM Coordinates Corner Southeast Corner Northing	UTM Coordinates Corner Southeast Corner Easting	Volume (m^3)	Area (m^2)	Depth (m)	Landfarm Closure Reference(s)
PIN-4 (Byron Bay, NU)	Nunavut Settlement Area (NSA)	Remediation complete.	n/a	Landfarm closed in 2011.	Berms flattened, and area reshaped.	n/a	No	Not calculated	2,100	7627787	581053	3,530	8,820	0.4	Environmental Sciences Group, 2010. PIN-4 (Byron Bay, Nunavut) Site Remediation: Confirmatory Sampling 2010.(Memo: ESG-PIN-4-196) Environmental Sciences Group, 2011. PIN-4 (Byron Bay, Nunavut) Site Remediation: Confirmatory Sampling 2011.(Memo: ESG-PIN-4-290)
CAM-M (Cambridge Bay, NU)	Nunavut Settlement Area (NSA)	Remediation complete.	n/a	No landfarm constructed.	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
CAM-1 (Jenny Lind Island, NU)	Nunavut Settlement Area (NSA)	Remediation complete.	n/a	Landfarm closed in 2009.	Berms flattened, and area reshaped. Liner removed.	n/a	Yes	350	1,800	7620206	388991	4,310	10,790	0.4	Environmental Sciences Group, 2010. CAM-1 (Jenny Lind Island, Nunavut) Site Remediation: Confirmatory Sampling, 2009 (Draft Report). (Memo: ESG-CAM-1-136)
CAM-2 (Gladman Point, NU)	Nunavut Settlement Area (NSA)	Remediation complete.	Cell 1	Cell 1 of landfarm closed in 2005.	Berms flattened, and landfarm covered with 0.3m of granular fill.	2,886	Yes	1,100	2,500	7618601	548395	3,850	9,620	0.4	Environmental Sciences Group, 2010. CAM-2 (Gladman Point, Nunavut) Site Remediation: Confirmatory Sampling 2005. (Memo: ESG-CAM-2-107)
	Nunavut Settlement Area (NSA)		Cell 2.1	Cell 2.1 of landfarm closed in 2005.		2,016	Yes	1,200	8500[2]	548403	548403	4,330	6,720	0.6	Environmental Sciences Group, 2010. CAM-2 (Gladman Point, Nunavut) Site Remediation: Confirmatory Sampling 2005. (Memo: ESG-CAM-2-104)
			Cell 2.2	Cell 2.2 of landfarm closed in 2005.		1,035	Yes	1,400	4,200	7618515	548436	2,070	3,450	0.6	Environmental Sciences Group, 2010. CAM-2 (Gladman Point, Nunavut) Site Remediation: Confirmatory Sampling 2005. (Memo: ESG-CAM-2-087)
CAM-3 (Shepherd Bay, NU)	Nunavut Settlement Area (NSA)	Remediation complete.	n/a	Landfarm closed in 2007.	Berms flattened and area reshaped.	n/a	No	470	1,300	7631479	483192	6,080	15,190	0.4	Environmental Sciences Group, 2008. CAM-3 (Shepherd Bay, Nunavut) Site Remediation: Confirmatory Sampling 2007. (Memo: ESG-CAM-3-098)

DEW Line Cleanup Landfarm Summary, cont'd

Site Name	Land Claims Region	DLCU Site Status	Landfarm Sub-Sections	Landfarm Status	Closure	Cover Material Volume (m^3)	Tier I/ Type B Cell	TPH Concentration (95% UCL Mean)[1] [ppm]	TPH Concentration (Maximum) [ppm]	UTM Coordinates Corner Southeast Corner Northing	UTM Coordinates Corner Southeast Corner Easting	Volume (m^3)	Area (m^2)	Depth (m)	Landfarm Closure Reference(s)
CAM-4 (Pelly Bay, NU)	Nunavut Settlement Area (NSA)	Remediation complete.	Lower Site	Landfarm closed in 2006.	Landfarm used to treat soil in two lifts, contents consolidated to 1.0 m depth, berms flattened and covered with 0.3 m of granular fill.	1,050	No	810	4,200	7593889	392619	1,400	3,500	0.4	Environmental Sciences Group, 2007. CAM-4 (Pelly Bay, Nunavut) Site Remediation: Confirmatory Sampling 2006. (Memos: ESG-C4-151 and ESG-C4-154)
CAM-5 (Mackar Inlet, NU)	Nunavut Settlement Area (NSA)	Remediation complete.	North	Landfarm closed in 2010.	Landfarm used to treat soil in two lifts, contents consolidated to 0.8 m depth, berms flattened and area reshaped. Some section of liner removed.	n/a	No	1,039	4,900	7581242	553191	6,018	7,523	0.8	Environmental Sciences Group, 2010. CAM-5 (Mackar Inlet, Nunavut) Site Remediation: Confirmatory Sampling 2010 (Draft Report). (Memo:ESG-CAM-5-335 and -490)
			South	Landfarm closed in 2010.	Berms flattened and area reshaped. Some sections of liner removed.	n/a	No	676	2,800	7581206	553224	3,033	7,583	0.4	Environmental Sciences Group, 2010. CAM-5 (Mackar Inlet, Nunavut) Site Remediation: Confirmatory Sampling 2010 (Draft Report).(Memo:ESG-CAM-5-490)
			Extension	Landfarm closed in 2010.	Berms flattened and area reshaped. Some sections of liner removed.	n/a	No	676	2,800	7581177	553249	1,840	4,600	0.4	Environmental Sciences Group, 2010. CAM-5 (Mackar Inlet, Nunavut) Site Remediation: Confirmatory Sampling 2010 (Draft Report).(Memo:ESG-CAM-5-490)

DEW Line Cleanup Landfarm Summary, cont'd

Site Name	Land Claims Region	DLCU Site Status	Landfarm Sub-Sections	Landfarm Status	Closure	Cover Material Volume (m^3)	Tier I/ Type B Cell	TPH Concentration (95% UCL Mean)[1] [ppm]	TPH Concentration (Maximum) [ppm]	UTM Coordinates Corner Southeast Corner Northing	UTM Coordinates Corner Southeast Corner Easting	Volume (m^3)	Area (m^2)	Depth (m)	Landfarm Closure Reference(s)
FOX-M (Hall Beach, NU)	Nunavut Settlement Area (NSA)	Remediation complete.	HCSSA	Landfarm closed in 2007.	Berms flattened and area reshaped. Some sections of liner removed.	n/a	No	280	4,300	7627239	491275	11,730	29,370	0.4	Environmental Science Group, 2008. FOX-M (Hall Beach, Nunavut) Site Remediation: Confirmatory Sampling 2007. (Memos: ESG-FOX-M-325 and ESG-FOX-M-372)
			Main	Landfarm closed in 2007.	Berms flattened and area reshaped. Some sections of liner removed.	n/a	No	360	2,500	7627215	491300	20,190	50,480	0.4	Environmental Science Group, 2008. FOX-M (Hall Beach, Nunavut) Site Remediation: Confirmatory Sampling 2007. (Memo: ESG-FOX-M-372)
FOX-2 (Longstaff Bluff, NU)	Nunavut Settlement Area (NSA)	Remediation complete.	North	Landfarm closed in 2010.	Berms flattened and area reshaped.	n/a	Yes	503	2,100	7646767	489101	3,730	9,327	0.4	Environmental Science Group, 2010. FOX-2 (Longstaff Bluff, Nunavut) Site Remediation: Confirmatory Sampling 2010(Draft Report). (Memo: ESG-FOX-2-242)
			South	Landfarm closed in 2010.	Berms flattened and area reshaped.	n/a	No	1,312	4,729	7646675	489211	3,501	8,753	0.4	Environmental Science Group, 2010. FOX-2 (Longstaff Bluff, Nunavut) Site Remediation: Confirmatory Sampling 2010(Draft Report). (Memo: ESG-FOX-2-187 and 242)
FOX-3 (Dewar Lakes, NU)	Nunavut Settlement Area (NSA)	Remediation complete.	n/a	Landfarm closed in 2011.	Berms flattened and area reshaped.	n/a	No	Not calculated	2,080	7616842	409393	1,240	6,200	0.2	Environmental Sciences Group, 2011. FOX-3 (Dewar Lakes, Nunavut) Site Remediation: Confirmatory Sampling 2011 (Draft Report). (Memo ESG-FOX-3-348)
FOX-4 (Cape Hooper, NU)	Nunavut Settlement Area (NSA)	Remediation complete.	n/a	No landfarm constructed.	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

DEW Line Cleanup Landfarm Summary, cont'd

Site Name	Land Claims Region	DLCU Site Status	Landfarm Sub-Sections	Landfarm Status	Closure	Cover Material Volume (m^3)	Tier I/ Type B Cell	TPH Concentration (95% UCL Mean)[1] [ppm]	TPH Concentration (Maximum) [ppm]	UTM Coordinates Corner Southeast Corner Northing	UTM Coordinates Corner Southeast Corner Easting	Volume (m^3)	Area (m^2)	Depth (m)	Landfarm Closure Reference(s)
FOX-5 (Broughton Island, NU)	Nunavut Settlement Area (NSA)	Remediation complete.	Station	Landfarm closed in 2006.	Landfarm used to treat soil in two lifts, contents consolidated to 1.0 m depth, berms flattened and covered with 0.3 m of granular fill.	1,998	No	1,400	4,500	7491353	466603	6,660.80	16,652	0.4	Environmental Sciences Group, 2007. FOX-5 (Qikiqtarjuaq, Nunavut) Site Remediation: Confirmatory Sampling 2006. (Memo: FOX-5-097)
			Airstrip	Landfarm closed in 2006.	Berms flattened, and landfarm covered with 0.3m of granular fill.	1,905	No	880	3,500	7492144	455939	6,350	15,870	0.4	Environmental Sciences Group, 2007. FOX-5 (Qikiqtarjuaq, Nunavut) Site Remediation: Confirmatory Sampling 2006. (Memo: FOX-5-086)
DYE-M (Cape Dyer, NU)	Nunavut Settlement Area (NSA)	Remediation in progress.	Hectare 1	Landfarm closed in 2009.	Cell was reshaped	TBD	No	700	4,400	7387850	562812	4,490	11,220	0.4	Environmental Sciences Group, 2010. DYE-M (Cape Dyer, Nunavut) Site Remediation: Confirmatory Sampling 2009 (Draft Report). (Memo: ESG-DYE-M-469)
			Hectare 2	Landfarm closed in 2009.	Cell was reshaped	TBD	No	1,000	4,900	7387809	562836	4,070	10,170	0.4	Environmental Sciences Group, 2010. DYE-M (Cape Dyer, Nunavut) Site Remediation: Confirmatory Sampling 2009 (Draft Report). (Memo: ESG-DYE-M-469)
			Hectare 3	Landfarm currently in use.	TBD	TBD	No	TBD	TBD	7387704	562730	4,250	10,630	0.4	TBD
			Tier I/Type B	Landfarm closed in 2009.	Cell to be covered with minimum of 0.3 m clean fill.	TBD	Yes	Not calculated	950	7387725	562892	1,710	4,280	0.4	Environmental Sciences Group, 2010. DYE-M (Cape Dyer, Nunavut) Site Remediation: Confirmatory Sampling 2009 (Draft Report).(Memo: ESG-DYE-M-598)
			2008 Cell	Landfarm closed in 2009.	Cell was reshaped	TBD	No	Not calculated	580	7387821	562607	3,530	8,820	0.4	Environmental Sciences Group, 2010. DYE-M (Cape Dyer, Nunavut) Site Remediation: Confirmatory Sampling 2009 (Draft Report).(Memo: ESG-DYE-M-563)
			2009 Cell	Landfarm currently in use.	TBD	TBD	TBD	TBD	TBD	7387849	562603	236	590	0.4	TBD
			W22G	Landfarm currently in use.	TBD	TBD	TBD	TBD	TBD	7387719	562644	6,800	17,000	0.4	TBD

(1) 95% or 97.5% based on what was reported at each individual site at the time of landfarm closure.

(2) The area around sample with TPH concentration of 8,500 ppm was later removed to the Tier II facility. Concentrations in this cell may still exceed 5,000 ppm.

4 Potential Use of Remediated Landfarm Soils

On behalf of the North Warning System Office (NWSO), the DLCU PMO asked ESG to examine the potential for use of remediated landfarm soils for other on-site purposes, such as construction of or repairs to gravel pads, roadways and airstrips. Before these soils are used elsewhere on site, their potential to have negative impacts on the area in which they would be used must be examined.

4.1 Information Requirements

The TPH concentration of the remediated soil must meet the conditions outlined in the DLCU Landfarm Evaluation Protocol (ESG 2003 and 2005) in order for the landfarm to be closed. In other words, the average TPH concentration of the soil must be below 2,500 ppm, with no single sample having a concentration in excess of 5,000 ppm. It is important to recognize that biodegradation and volatilization of the Type B hydrocarbons in the soil will continue after closure of the landfarm so concentration of contamination will continue to decrease over time at a slower rate than during active landfarm treatment.

If remediated soil is to be used elsewhere on site, the current TPH concentration in the soil must be measured and assessed against a numerical objective to determine whether the soil's use in a specific location poses a risk to the environment.

4.2 Considerations for Reuse

4.2.1 Presence of Co-contamination

In most cases, soil that was placed in the landfarm for remediation was contaminated only with Type B hydrocarbons. Prior to its treatment in the landfarm facility, the Type B hydrocarbon-contaminated soil was sampled in its original location. Soil samples were analyzed for inorganic elements (specifically, arsenic, cadmium, copper, cobalt, chromium, lead, and zinc), polychlorinated biphenyls (PCBs) and TPH. Contaminant concentrations were compared to the DEW Line Cleanup Criteria (DLCC). Soil containing Type B TPH and inorganic elements and/or PCBs above the applicable Tier II levels of the DLCC was not placed in the landfarm facility but was disposed as Tier II-contaminated soil either in an on-site Tier II landfill facility or shipped off-site.

However, at some sites, a separate cell within the landfarm was constructed for the treatment of soils co-contaminated with Type B hydrocarbons and DLCC Tier I lead and/or

PCBs. These areas must be capped with a minimum of 30 cm of clean fill prior to landfarm closure, and must be indicated on drawings completed as part of the site closeout. These soils should not be removed from the remediated landfarm and used elsewhere on site.

4.2.2 Other Considerations

In addition to the final measured TPH concentration in the landfarm soil, several other factors should be examined when considering the potential use of this soil elsewhere on site. These include (but are not limited to):

- the nature of the soil within the landfarm (i.e., coarse or fine-grained);
- the location in which the soil will be used (e.g., proximity to water bodies and groundwater; susceptibility to erosion; underlying geology); and
- Potential exposure to receptors (human, wildlife and plant and aquatic life)

Guidance for evaluating the risk associated with the use of remediated soil is available from the DLCU hydrocarbon risk evaluation protocol (EWG 2003) and the Canadian Council of Ministers of the Environment Canada-wide Standard for Petroleum Hydrocarbons (CCME CWS PHC). In addition, Indian and Northern Affairs Canada (INAC), now Aboriginal Affairs and Northern Development Canada (AANDC), developed remedial objectives for use at abandoned military sites in the Arctic using information contained in both the CCME CWS PHC and the DEW Line Cleanup Protocol. A summary of each approach is given below.

4.2.2.1 The DLCU Approach

For the DLCU Project, the risk posed by hydrocarbon contamination is evaluated using a risk evaluation methodology that was developed by the Environmental Working Group (EWG) in 1999 and updated in 2003. This is a two-part evaluation process; first, the Likelihood of Exposure is examined qualitatively using simplified decision-making criteria and the Receptor Sensitivity in the contaminated area is assessed. Appropriate risk mitigation measures are then determined based on a qualitative evaluation of the Receptor Sensitivity relative to the Likelihood of Exposure. Site-specific factors are considered when the evaluator's professional judgment suggests that the Likelihood of Exposure and/or the Receptor Sensitivity may be higher or lower than the evaluation process indicates (EWG 2003).

4.2.2.2 Canadian Council of Ministers of the Environment (CCME) Canada-wide Standard for Petroleum Hydrocarbons

The CCME endorsed the Canada-wide Standard for PHC in soil in 2001 (CCME 2001). The guidelines were updated in 2008 to include updated toxicological information (CCME 2008). The CCME CWS PHC is a three-tiered risk-based assessment standard for contaminated soil and subsoil occurring in four land-use categories; agricultural, residential/parkland, commercial and industrial. For DEW Line sites, the residential/parkland category is used because this will reflect the potential end use of the site following remediation. Tier 1 sets generic numerical levels; Tier 2 allows for adjustments to Tier 1 levels based on site-specific information; and Tier 3 involves a site-specific risk assessment (CCME 2008). This approach is similar to that developed by the EWG, except that the EWG approach incorporates concerns specific to the Arctic environment (EWG 2003).

4.2.2.3 Indian and Northern Affairs Canada (INAC) Abandoned Military Site Remediation Protocol

The INAC (now AANDC) Abandoned Military Site Remediation Protocol (INAC AMSRP), first published in 2005, is "based on an approach that addressed legal requirements, INAC's Contaminated Sites Policy (including risk management requirements), and standard environmental practices" (INAC 2005). In 2009, the document was revised and is currently in use to guide the remediation of abandoned military sites (including former DEW Line sites) that are managed by INAC (INAC 2009 a).

INAC has adopted the same classification system for hydrocarbon-contaminated soil as the system used for the DLCU Project. Two classes, Type A and Type B, are defined (INAC 2009 a, b), and the classification is related to a distinction of hydrocarbons by fraction, as in the CCME CWS. For a soil's hydrocarbon contamination to be classified as Type A, the sum of F3 and F4 fractions must be greater than 70% of the TPH concentration *and* the F2 concentration must be lower than the F4 concentration (INAC, 2009 a). The TPH concentration of Type B soil is equal to the sum of the F1, F2 and F3 fractions (INAC 2009 a). In cases in which all four hydrocarbon fractions are present in the soil, the dominant hydrocarbon type is determined by the sum of F3 and F4 fractions as a percentage of the TPH (INAC 2009 a).

The INAC AMSRP requires the remediation of free phase hydrocarbons at all sites (INAC 2009a). A review of the assumptions used for the interpretation of the CCME guidelines as well as the need to minimize physical disturbance suggested that direct application of the CCME guidelines may not be appropriate at the INAC sites (INAC 2009 a). The INAC

objectives for hydrocarbon evaluation therefore incorporate the CWS for PHCs as appropriate, but also align with the site-specific target levels and the DLCU approach (INAC 2009 a,b).

Table 1 summarizes the INAC AMSRP Remedial Objectives for Hydrocarbon-impacted Soils. When contaminated soil is located within 30 m of a water body, the remedial objective for the *Protection of Freshwater Aquatic Life* (i.e., 330 ppm for Type B hydrocarbons) is used. For areas well removed from water bodies, a remedial objective of 2,500 ppm TPH is applied for soils up to a depth of 0.5 m, and a management limit of 5,000 ppm TPH is used at depths greater than 0.5 m (based on professional judgement and site-specific conditions).

Table 2: INAC Abandoned Military Sites Remedial Objectives for Hydrocarbon Contaminated Soil

Exposure Pathway	Compound of Concern				
	F1 (C6–C10)	F2 (>C10–C16)	F3 (>C16–C34)	F4 (>C34)	Type B Hydrocarbon Contamination
	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]
Protection of freshwater aquatic life[a]	1,290[a]	330[a]	N/A	N/A	330[a]
Soil eco-contact	Not utilized[b]				
Protection of terrestrial wildlife					2,500[c]
Human health		11,000	20,000		
Management limit					5,000[d]

[a] Within 30 m of a water body
[b] See AMSRP Volume 2 (INAC 2009b)
[c] For surface soils to 0.5 m below ground surface (bgs)
[d] Below 0.5 m bgs, a value of 5,000 ppm may be applied based on professional judgement

The INAC Remedial Objectives for Hydrocarbon Soil were designed specifically for use during the remediation of abandoned military sites in the Canadian Arctic. These include the INAC DEW Line sites, which are similar in layout and location to the DND DEW Line sites. Thus, the establishment of these objectives has already considered the potential impacts that any exposure to hydrocarbon-contaminated soil may have on the receptors present. For these reasons, the INAC Remedial Objectives for Hydrocarbon-impacted Soil are most relevant when assessing the suitability for on-site use of remediated landfarm material.

5 Conclusions and Recommendations

The intent of the DEW Line Clean Up Project is to minimize risk to the Arctic ecosystem, including the food chain, by restoring the sites to an environmentally safe condition. The method of remediating Type B hydrocarbon-contaminated soils chosen for the DLCU Project is treatment in a landfarm facility.

The DLCU Project Landfarm Evaluation Protocol includes specific requirements for the closure of landfarms, including maximum permissible TPH concentrations in the soil. In order for a landfarm to be closed, the average TPH concentration in the soil must not exceed 2,500 ppm, with no single sample containing TPH at a concentration above 5,000 ppm. Biodegradation and volatilization of the Type B hydrocarbons in the soil continue after closure of the landfarm, resulting in subsequent TPH concentrations that may be below the levels required for closure.

ESG recommends that the use of remediated landfarm material for other purposes at former DND DEW Line sites be examined on a case-by-case basis. If use of the material elsewhere on site is desired, collection and analysis of soil samples from the former landfarm area is recommended to provide accurate information on the current concentrations of potential contaminants in this material. In addition to the current measured TPH concentration in the landfarm soil, several other factors should be examined when considering the potential use of this soil. These factors include (but are not limited to): the nature of the soil within the landfarm (i.e., coarse or fine-grained); the location in which the soil will be used (i.e., proximity to water bodies and groundwater; susceptibility to erosion; underlying geology); and potential exposure to receptors (i.e., human, wildlife and plants). For assessment of the suitability of remediated landfarm material for on-site use for other purposes, the INAC Remedial Objectives for Hydrocarbon Soil are the most relevant.

6 References

Canadian Council of Ministers of the Environment (CCME 2008). Canada-wide Standard for Petroleum Hydrocarbons (PHC) in Soil.

Canadian Council of Ministers of the Environment (CCME 2001). Canada-wide Standard for Petroleum Hydrocarbons (PHC) in Soil: User Guidance. O'Connor Associates Environmental Inc. and Meridian Environmental Inc. on behalf of Canadian Council of Ministers of the Environment.

Director General Environment (DGE 1996). Cooperation Agreement Between the Inuvialuit Regional Corporation and the Department of National Defence Concerning the Restoration and Clean-up of DEW Sites within the Inuvialuit Settlement Region.

Director General Environment (DGE 1998). Agreement Between Nunavut Tunngavik Incorporated and her Majesty in the Right of Canada as Represented by the Minister of National Defence for the Clean-up and Restoration of Distant Early Warning Sites within the Nunavut Settlement Area.

Environmental Sciences Group (ESG 1992). North Warning System Environmental Study. Prepared for the Director, North Warning System Office.

Environmental Sciences Group (ESG 2003). DEW Line Cleanup Sampling and Analytical Methods 2003. Royal Military College of Canada, Kingston, ON

Environmental Sciences Group (ESG, 2005). DEW Line Cleanup Sampling and Analytical Methods 2005. Royal Military College of Canada, Kingston, ON.

Environmental Working Group (EWG 2003). DEW Line Cleanup, Nunavut, Environmental Working Group Report.

Indian and Northern Affairs Canada (INAC 2009a). Abandoned Military Site Remediation Protocol, Volume I—Main Report. Indian and Northern Affairs Canada—Northern Affairs Organization's Contaminated Sites Program.

Indian and Northern Affairs Canada (INAC 2009b). Abandoned Military Site Remediation Protocol, Volume II—Technical Supporting Documentation. Indian and Northern Affairs Canada—Northern Affairs Organization's Contaminated Sites Program.

Indian and Northern Affairs Canada (INAC 2005). Abandoned Military Site Remediation Protocol. Indian and Northern Affairs Canada—Northern Affairs Organization's Contaminated Sites Program.